KALEP – An Engineering Education Model Supported by Modern IT-solutions

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Abstract

The objective of academic education for mechanical design engineers is to impart competencies which are necessary for product development in industrial surroundings. Graduates need professional engineering skills as well as other key competencies in fields like problem solving, ideation and also knowledge management. For meeting these requirements the Karlsruhe Education Model for Product Development (KALEP) [1.] was developed at IPEK, the Institute of Product Development. In this contribution we present KaLeP, the role of modern design tools like CAD/PDM and wikis in KaLeP as well as the application in the course projects for Machine Design, a pre-diploma course with approx 550 students, and Integrated Product Development, a final year design course with 42 selected students. Furthermore the training concept and the technical and organizational environment in which these courses take place are presented.

Introduction

The Institute of Product Development (IPEK) is an institute in the faculty of mechanical engineering at the University of Karlsruhe (TH) in Germany. The unifying goal of the research at IPEK is to improve product development processes and engineering design education simultaneously in the Humboldtian sense. To this end the special Karlsruhe Education model for Product Development (KaLeP) [1.] was developed at IPEK. Product design is more and more subject to a rising demand for efficiency. One Problem is that design cannot be taught sufficiently in lectures alone and that requirements on graduates in design are continuously increasing, not only for professional skills but also for social skills as well as proficiency with new technologies and methods. The overall goal of this work is to improve design education and to provide a more active learning experience by giving students hands-on experience with modern methods and technology which they will most likely encounter during their careers. To better achieve this goal, wikis, a CAD/PDM environment and other tools for knowledge and project management were provided to 550 second year university students for use in a design project, and to 42 selected students in a final year design course.

KaLeP

Modern theories of education say that taught knowledge cannot be cloned into the brain of learners. They have to construct this knowledge individually and embed it into their previous knowledge to understand it. Albers et al. [1, 2.] developed an education model that takes into account these special needs of learning. KaLeP was introduced in the year 1999 at IPEK and it has been continuously developed since [2.]. It is suitable to address issues in engineering design education as described in a study of the German Chamber of Industry and Commerce [3.]: The main reasons for dismissal are the disability of job entrants to transfer theoretical knowledge into practice and furthermore the job entrants' overestimation of their own capabilities. A lack of key qualifications and systematic proceeding was also identified.

To improve this situation and to impart knowledge in a possibly practicable form, KaLeP is based on three elements: Lecture, practice/workshop, and project work. This measure enables the effective teaching of theoretical matter (lecture), the demonstration of its application in example and practice (practice/workshop) and the intensive experience of realistic work (project team work) supplemented by regular review meetings. The utilization of CAD/PDM and Wikis in the context of KaLeP is the logic step to make the work environment for the students as efficient and realistic as possible.

PDM/CAD in design education

CAD-Software has become a standard in almost all sectors of mechanical engineering. This goes along with huge amount of data that needs to be handled. That and the increasing complexity in product, process and organizational structures in modern companies makes it difficult to work efficiently. A way to handle this complexity is to control the data and information flow combined with a predefined product structure. Product Lifecycle Management (PLM) -Systems are software solutions to achieve this [4.]. Therefore the companies expect experience with working within such environments. This demand has been addressed by universities in various ways.

In various publications ideas and requirements for the integration of CAD and PDM into education have been expressed. Bitzer et al. has proposed an education concept in which the necessary theoretical engineering background, soft skills and the usage of CAX-Systems is taught accompanied by work on projects derived from industrial design tasks [5.].

This has been addressed by Feldhusen in the undergraduate course "Introduction to CAD". Next to a project task supplied by an industrial partner the students from Aachen were teamed up with students from the Korean Hongik University in Seoul [6.].

Watty and Binz comment on the experiences with the introduction of project based work in second semester design courses and give an interesting insight on how to overcome heterogeneous team compositions and to ensure equal learning opportunities[7.].

Wikis in design education

Wikis are software systems, which allow users to easily generate, publish and edit web pages. Wikis have become increasingly popular mainly due to the following advantages: Easy collaboration and formation of opinion, easy documentation and editing, easy cross-linking between pages, full text search and most wikis are free and open source. Advantages of wiki use in design include the potential for increased reflection and development of shared understanding [8.], improved concept generation [9.], and easier design reuse. These features make wikis a suitable platform for exploration in design team settings. Hill et al. state that "communication in a social setting is often characterized as the creation of shared understanding through interaction among people" and that development of shared understanding is a key factor in high performing teams [8.]. Wikis are becoming increasingly popular also in design education. At Stanford University, Chen et al explored how the use of wikis and weblogs in combination with the pedagogic approach of Folio Thinking in design courses can have a positive effect on students' knowledge and skills in engineering design [10.]. Wodehouse et al. presented a study of third year design engineering students who were using a TikiWiki, for solving a design task [9.]. Results showed that using the wiki helped students to generate product concepts. In general, wikis seem to be a suitable tool for design and design education.

Training in CAD/PDM

In order to meet the requirement of computer skills in the engineering domain, students of Mechanical Engineering learn using Computer Aided Design (CAD) Systems, such as Pro/Engineer. It is important to educate students with the methodology of CAD and its integration in real product development problems [11.].

The goal for the recently conducted extension of CAD education at IPEK was to offer it to all students and to supply advanced Product Data Management (PDM) functionalities within an extended network, integrating students private Laptops into the IPEK CAD/PDM environment. Besides for infrastructural reasons, the introduction of a PDM system also allows to fit the CAD training better to very modern working techniques and working environments, like in the automotive or aircraft industry.

The goal of CAD training together with Machine Design education consists of building competencies of the students in the following fields:

- user interfaces
- design principles
- model topologies
- engineering design features
- assembly design
- 2D engineering drawing design
- workflows within CAD and PDM
- CAD model management
- CAD data management
- Rendering images and clips

Each student has an individual login, but is also member of a Machine Design class team with four other members. Inside the PDM system students can find their product represented by a Commonspace folder structure. By exploring the learning materials available in the PDM system, the student automatically gathers experience with the PDM system

Knowing already a lot about design features like shaft fits or threaded holes, the students can implement their knowledge seamlessly in simple CAD models. It is a strong component of Machine Design education at IPEK to develop a working technique focusing on a structured way of implementing functions into a geometric design.

Right after the parts and Bottom-Up assembly design, an advanced topic is introduced: Top-Down assembly design. Top-Down design allows defining a product on a very abstract level, without focusing too much on the volume design. Using so called skeletons is a good method for teams to fix certain common references which are important for more than one part. Students do not only learn how to model 3D geometries, but are also educated with classical associative 2D drawing derivation out of 3D models. During the above mentioned CAD tasks the students are permanently using PDM functionalities such as "check-in" and "check-out", model previewing, model updating in assemblies, moving, renaming and deleting CAD data. Such many common PDM tasks become routine behavior, particularly team related data management tasks.

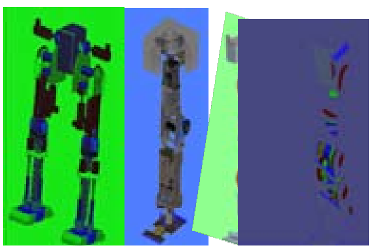
IT Infrastructure and Working Environment

The technical implementation of the goals described above is somewhat difficult due to the large number of students in the pre-diploma-studies. The current amount of 150 work-stations at IPEK only allows a part of these students to do their project work. The external access to the web-based PDM-System PTC PDM-Link enables the students to also work from within the campus wireless-lan or their homes and is therefore virtually extending the amount of available Workstations. The Institute is supplying the students with student licenses accompanied by customized installing procedure to ensure, that the local PTC ProEngineer installation meets the institutes standards. This has proven to be an efficient way of reducing the amount of support the students need in operating the software.

Mechanical Design Course

During their pre-diploma studies, students of Mechanical Engineering at the University of Karlsruhe have to participate in a mechanical design course for four consecutive semesters. During the fourth mechanical design course students have to solve a complex design task in teams of 5 students. In the summer semester 2008 the project task was to design legs for a humanoid robot. This challenging but realistic task was divided into three phases. After each phase, the student teams presented their design solutions, received feedback on their work and discussed their progress with student tutors and academic assistants. During the first phase, students gathered, synthesized and presented information about the state of the art in bipedal locomotion for humanoid robots, actuators, sensors and transmission elements. To collect this information, the students were provided a wiki. At the end of the first phase the students were given access to all information the other 600 students had gathered, to provide them with a huge knowledge base. During the second phase, students generated ideas and concepts for the design of robotic joints. During the third and final phase, students finished the embodiment design for a pair of humanoid robot legs. To ensure the quality of the learning experience IPEK has established a student feedback team which reports directly to the head of the institute. The best 5 groups were awarded and got the possibility to present their design results in front of all the other students. Figure 1 shows examples for robot legs designed in this course.

Figure 1: Exemplary Final Design Results for humanoid robot leg



Final Year Design Course Integrated Product Development

One of the core elements of KaLeP is the final year design course Integrated Product Development. It consists of lectures, workshops and a design project in cooperation with an industry partner. The overall concept of this course enables the students to experience a product development process from market analysis to first prototypes. Due to the effort for intensively coaching the students, the course capacity is currently limited to 42 students in 7 teams. To provide a realistic setting for the design project, the students need to solve an open and complex product development problem from an industrial partner. The student teams are given a realistic working environment including their own cubicle. These cubicles are equipped with modern workstations and provide enough work space for the complete team. Another means to create a realistic environment is the simulation of an organizational structure that integrates the student teams and puts them into a slightly competitive position with the other teams. They are also given access to nearly the same infrastructure as it is used by the employees of the institute. This includes software for office tasks, CAD, PDM, CAE, project management, Wiki and document management. Throughout the project the students also have the possibility to build prototypes of their products in a dedicated student workshop in close proximity to their working cubicles.

The students receive regular coaching in weekly workshops. The range of topics spans for example creativity techniques, target costing or Scenario Management techniques. Even though the team structures in this project are relatively homogenous, problems in team work do arise. Later on in their professional career, the students will most likely work in teams which are more heterogeneous with more potential causes for team conflicts. To prepare the students for such conflicts and to provide them with possible solutions, the students receive coaching from a professional human resource consultant at the beginning of the project and, if problems arise, also during the project. The students also receive a dedicated CAD/CAE-training. At the end of the course they are also trained in processing the CAD-data for animations and rendered pictures. The teams need to plan their projects and have to present their results at predefined milestone presentations to the industry partner. At the end of the project the students get to present the final results of their work in a public presentation in front of representatives from industry, academia and family. This public presentation and the positive feedback which students normally receive is often a highlight in their curriculum and it is also an important compensation for the additional voluntary effort which most students put into this project. The regular presentations at the milestones and at the end of the project give the students not only an opportunity to train their design skills but also their presentation skills. Figure 2 shows a student prototype which was later further developed into a real product by the industrial partner.

Figure 2: Student prototype from Integrated Product Development project and final product

Summary and Future Work

The current state of engineering education at IPEK was described. It was shown how KaLeP is supplemented by modern ICT-solutions. The implementation of the education concept provides students with an active learning experience, which is also emphasized by the huge amount of extra time the students invest in their projects voluntarily. Future work will focus on a consolidated software variety and the provisioning of a single point of entry for PDM, document management and wikis. It is also planned to include students in sophisticated workflows, to facilitate user management and student assessment.

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